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Logistical Control of Flexible Processes in High-Throughput Systems by Order Release and Sequence Planning

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Abstract

High-Throughput Systems (HTS) are utilised predominantly in pharmaceutical and food industry as well as medical technology. Those rigidly linked systems with large outputs of up to 100,000 samples per day are used for screening or synthesis. The usage of HTS enables major increases in quantities and decreases in throughput time. With regard of testing materials in a HTS flexible processes and process inherent restrictions have to be controlled. Currently it has not been researched whether a logistical control method which is able to deal with these requirements exist. Due to this, in this early approach the influence of order release and sequence planning in a HTS with occurring ad hoc changes like partial testing and re-routing is considered and evaluated. The results demonstrate indicators for the development of a new generation of logistical control methods which enable production systems to produce a high number of variants in high volume.

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1. Introduction

High-Throughput Systems (HTS) facilitate tests of 10,000 to 100,000 and Ultra-High-Throughput Systems even more than 100,000 samples per day [1]. These systems are used for synthesis and screening in pharmaceutical and food industry as well as in medical technology [1-5]. For the implementation of HTS automation and robotics are mandatory. This causes high acquisition costs which are compensated by the advantages of HTS. The highest reduction of the costs can be achieved through the noticeable lower development costs and times [4] [5].

Most of conventional HTS are rigidly linked. They do not work as multi-purpose systems and execute one specified synthesis or screening. With regard to innovative, sustainable and resource-saving constructions it is necessary to use materials which possess requested characteristics. The target-oriented search of materials with defined characteristics causes a high volume of samples. HTS are suggested for finding structural material with the requested characteristics in a time and cost effective way. Testing material characteristics is a mostly iterative process that depends on the material and the requested characteristics. The identification of varying characteristics of material often has to be done with different testing procedures. The identification of structural material with specific requested characteristics in HTS is possible if every station in the system is embedded in one common logistic control method [6]. The process of testing materials is not rigidly linked as the screening in conventional HTS. Due to the target of testing more than one material characteristic there would appear flexible processes as well as ad hoc amendments. Therefore, a logistical control method is required.

The implementation of test methods in HTS could reduce the throughput time and increase the quantities dramatically. Due to the implementation of testing materials in HTS a system which is able to deal with a high variety and high volume should be achieved. In this early approach the effect on the throughput time and the average output caused by the

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application of order release and sequence planning has been simulated and evaluated.

2. Material testing in HTS

Identifying specific material characteristics in conjunction with varying material compositions may cause a high number of tests until the requested quality is achieved. The implementation of material testing in HTS enables the testing of these high volumes. Contrasting to conventional HTS, a HTS for material testing is a multi-purpose system which is able to measure different material characteristics like tensile strength and yield strength.

Schneider et al. pointed out that due to the implementation of material testing in HTS, restrictions like re-routings and partial testing have to be taken into account. Destroyed samples should not be measured. By ad hoc skipping these scrap the throughput time and the costs could be reduced, especially if high rates of scrap appear. Measured sample properties can influence the further testing process. On the basis of specific measurement results it can be necessary to re-route the test plan. These ad hoc re-routings can affect the subsequent testing sequence or single testing stations. One kind of ad hoc re-routing which impacts one testing station will occur if a measurement is incorrect. In this case the samples have to re-run the station for a retesting [6].

In contrast to conventional HTS, HTS for material testing requires high process flexibility as shown in table 1. Especially the varying process sequences and the undirected material flow lead to a high complexity with regard to the control of the system.

Table 1. characteristics of HTS.

characteristic	conventional HTS [1-5]	HTS for testing material characteristics [6]
material flow	directed	undirected
sample type	uniform	variable
amount of inspection	unique and complete	repetition check and skipping of damaged samples
process sequence	static	varying according to: • sample type • aim of analysis • test result

3. State of the art

Testing materials in HTS is an innovative approach. The effect of re-entrants in production systems which are similar to re-run one or more test stations was detected by Seleim and ElMaraghy. Their analysis of manufacturing systems showed that depending on its parameters simple re-entrants could have major impacts on the whole system. Due to this fact it is important to understand the dynamics of a production system with re-entrants. Especially if a system with re-entrants is a subsystem of a larger production system. In this case the output of the subsystem is the input of the other system. Through this the re-entrants influence following production steps as well [7]. Schneider et al. investigated the influence of partial tests and ad hoc re-routings including retesting in HTS for material testing [6]. These first simulations in a simplified environment show an increase of the throughput time of up to 23 % caused by retests and a decrease of up to 20 % caused by partial tests [6].

With regard to current literature, no logistical control method has been found, that is able to deal with the specific requirements of HTS (table 1).

There are existing approaches for the usage of workload control in job fabrication with high routing complexity but these apply on low quantities [8]. This paper shows a first approach for the enabling of logistical control of high volumes and high number of variants.

4. Logistical control method for testing materials in HTS

As described in section 2 the intended HTS has ad hoc varying processes like skipping of scrap and re-routing. Due to the fact that currently no logistical control method is able to deal with this complex processes a new logistical control method has to be developed.

The described versatility of the products in the purposed HTS for material testing is similar to job shop production as showed in table 2. Both show variable and recursive material flows as well as flexible process chains that depend on the request. In contrast to the job shop production the recursive material flow and the skipping of scrap are standard processes in HTS for material testing.

Table 2. similarities and differences comparing job shop production and HTS for material testing.

characteristic	job shop production	HTS for testing material
material flow	undirected	undirected
process chain	depending on order	depending on order
variety	high	high
re-routing	rare case, should be avoided	common, standard process

Due to the structural similarities between job shop production and HTS for material testing the influence of the option of using Decentralised Work in Process-oriented Manufacturing Control (DEWIP) as an element within the development of a new production planning and control algorithm has been evaluated.

The DEWIP by Lödding is based on a control loop between working stations before orders are released. This allows the integration of production´s workforce in the responsibility of achieving logistic targets. Every working station has a work in progress account in which upcoming orders are listed. Orders will be released if the following working station has not reached the limit of its account. The sequence in which the orders are proofed for release is built in accordance to the urgency of the orders. The sequence planning is the connection between the production planning and the DEWIP [9].

The described logistical control method has been modified